

Developing an artificial intelligence-based smart kitchen system to detect functional cognitive errors during a simple cooking task

Yejin Lee^{1,2}, PhD; Ruiqi Wang^{1,3}, Patrick Lynch^{1,3}, Peiqi Gao^{1,3}, M. Carolyn Baum^{1,2}, PhD; Chenyang Lu^{1,3}, PhD; Lisa Tabor Connor^{1,2}, PhD

1. AI for Health Institute, Washington University in St. Louis,
2. Program in Occupational Therapy, Washington University School of Medicine
3. Department of Computer Science and Engineering, Washington University in St. Louis

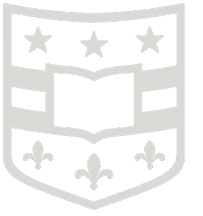
Supported by a WashU Here & Next grant to L. Connor & C. Lu



WashU Medicine



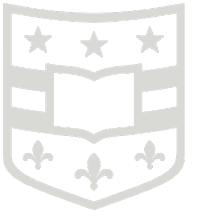
The Problem:



Many people with cognitive impairment struggle to complete daily activities without assistance

People with cognitive impairment can live more independently at home with cognitive supports

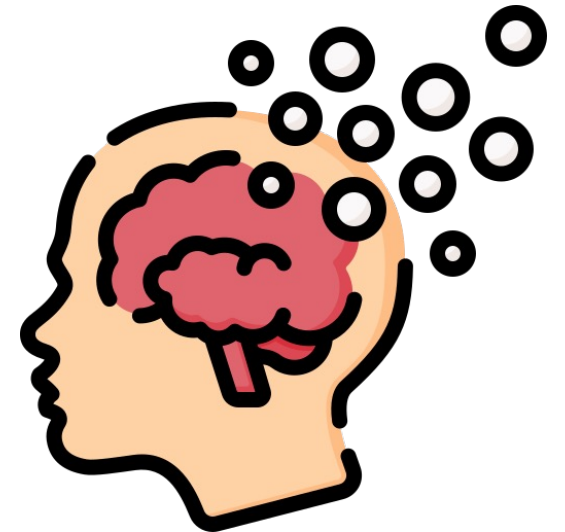




Why is this important?

Subjective Cognitive Decline (SCD) is self-reported MEMORY PROBLEMS that have been GETTING WORSE over the past year.

- 1 in 9 people over 45 experience SCD
- 30.3% of women with SCD live alone
- 35.5% of African Americans with SCD live alone



<https://www.flaticon.com>

Sources: CDC & Alzheimer's Association; National Post-Acute and Long-term Care Study (2020); National Poll on Healthy Aging (2022)



Source: National Poll on Healthy Aging (2022)

However,

- 88% of adults in the US age 50-80 believe that it is important to remain in their homes as long as possible
- Desire to age in place due to cost and importance of independence

Smart Kitchen System Development



Simple Cooking Task

Making oatmeal on the stove

+

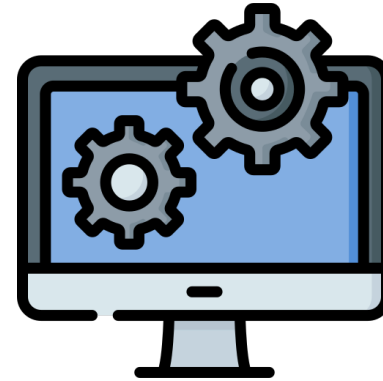


Video capture

Video capture people with SCD performing the task & making errors

Embedded AI computing platform

+



Performance Breakdown Recognizer

Train deep learning model with videos annotated with error types by clinicians

+



Adaptive Cueing Agent

Deliver context-sensitive cues to support performance by smart speaker

EFPT – What does it measure?

- The EFPT tells clinicians **the level of support** required for a person to be successful in 4 tasks that are required to be independent at home:



Simple Cooking
(Oatmeal Making)



Paying bills



Making a telephone call



Taking medication

EFPT – What does it measure?

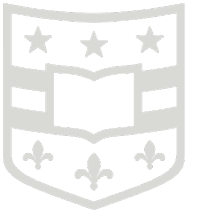
This is a performance-based assessment

- Client must do each activity to its completion
- Following instructions
- In order
- In a dynamic environment
- If errors are made, clinician must give progressively more supportive cues
- Progressive cues must be given in a timely manner, but not too soon so that client can process the cue (challenging!)

Experimental Setup



Fig. 1. Smart Kitchen setup for the project and data collection.



Data Collection

- Behavioral and contextual videos from 139 human participants
- All completed oatmeal preparation from the EFPT

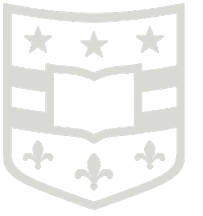
Oatmeal Cooking Instructions

1. Gather all the items needed from the box and place the items on the counter.
2. Boil water and salt on high (Boil Button).
3. Add oats in the boiled water.
4. Cook the oatmeal for two minutes by setting the timer over medium heat (Slow Cook Button).
5. Stir occasionally.
6. Serve the oatmeal to the tester.
7. Put the dirty dishes in the sink.

Participant Demographics and Cognitive Characteristics



Variable	Value	Variable	Value
Sex, n	107	Race, n	107
Male	41	Black or African American	6
Female	66	White/Caucasian	75
		Asian	22
		Other	4
Age		Education (Years)	
Average	51.36	Average	16.19
Standard Deviation	19.00	Standard Deviation	2.33
Minimum	21	Minimum	10
Maximum	82	Maximum	20
Cognitive Status			
Self-reported SCD	27 (25.23%)		
Mild Cognitive Impairment	22 (20.56%)		



Annotation of Videos by OTs

- ELAN 6.7 software to develop action recognition dataset

- | | |
|------------------------------------|-----------------------------------|
| 0. Transitioning | 1. Gathering the Items |
| 2. Opening the Oat Container | 3. Measuring the Oats |
| 4. Measuring the Water | 5. Measuring the Salt |
| 6. Placing the Pan on the Stove | 7. Closing the Oat Container |
| 8. Putting the Oats in the Pan | 9. Putting the Water in the Pan |
| 10. Turning on the Stove | 11. Setting the Timer |
| 12. Changing the Temperature | 13. Turning off the Stove |
| 14. Putting the Oats into the Bowl | 15. Putting the Dirty Dishes Away |

The CHEF-VL algorithm sequentially processes each incoming predicted action. It evaluates each action's dependency constraints and prerequisite constraints.

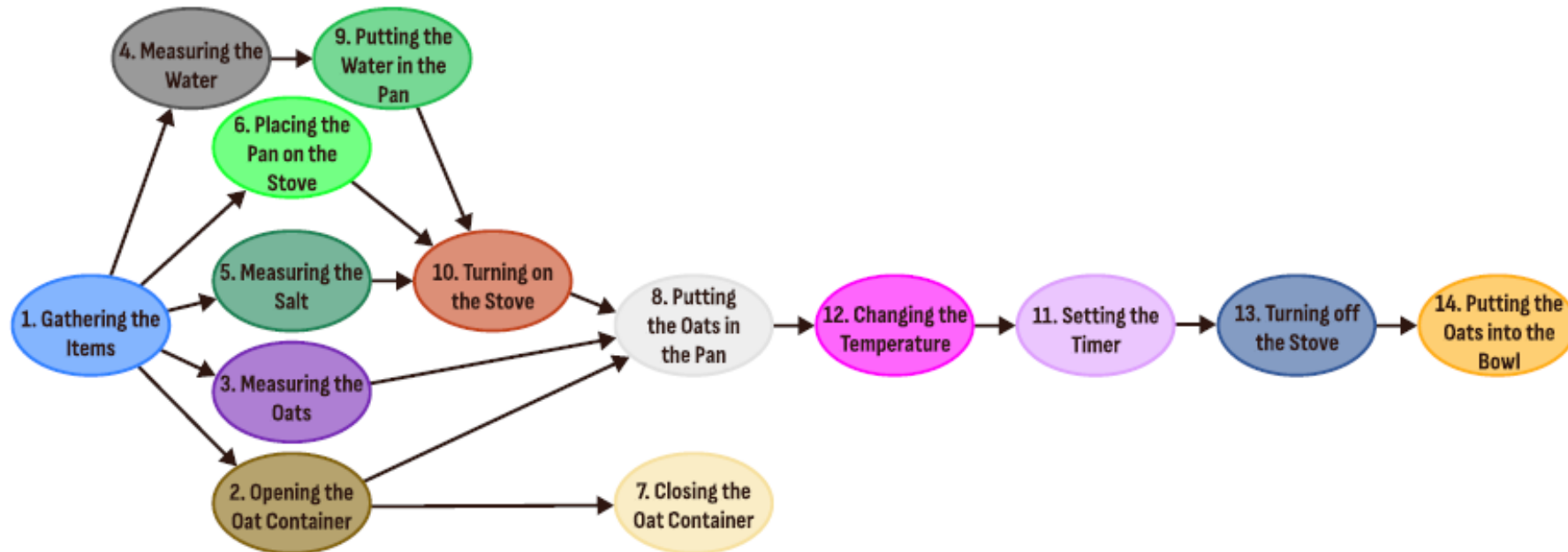


Fig. 4. The sequencing requirements of the oatmeal cooking task represented by a Hasse diagram of a partial order.

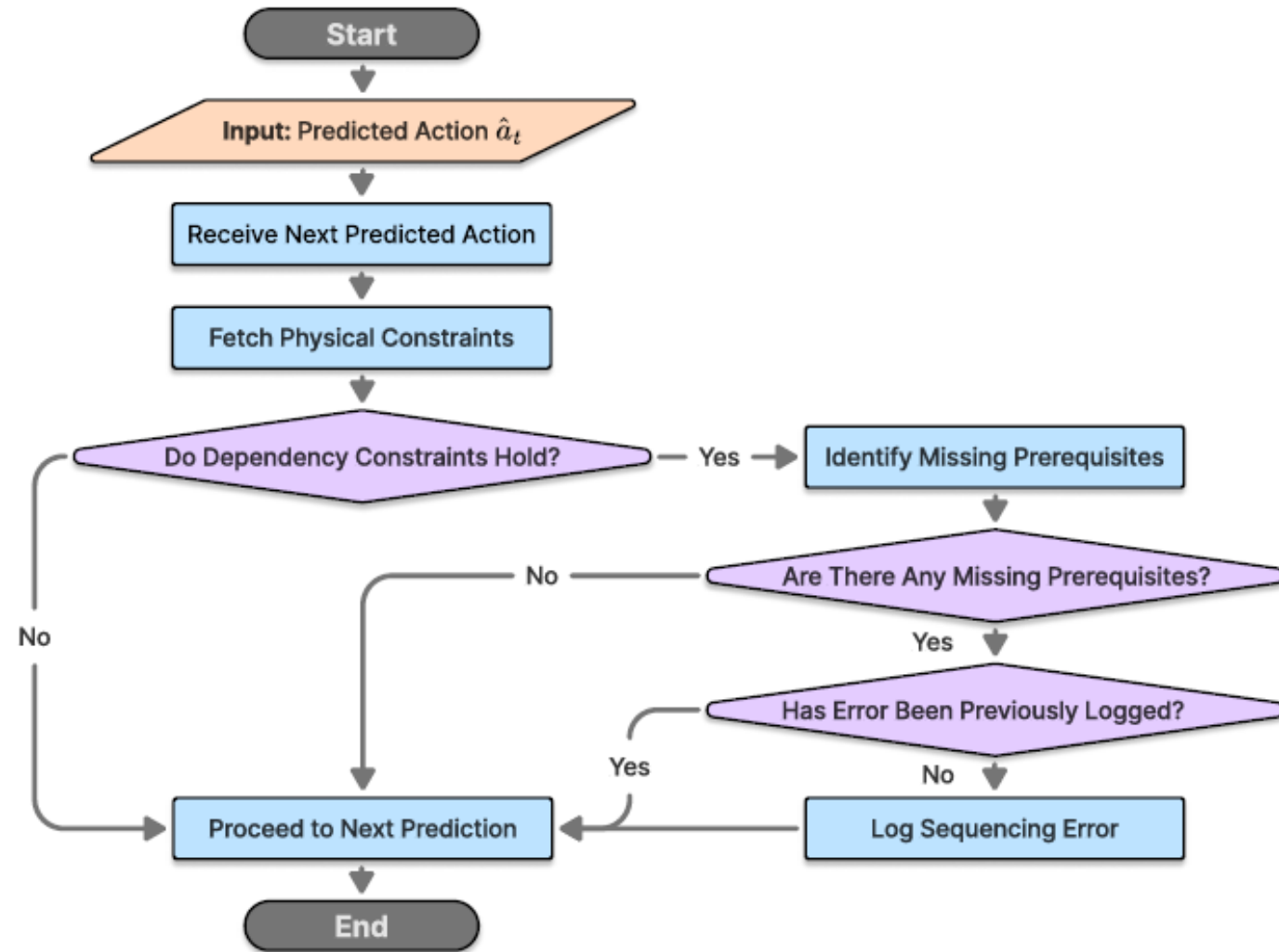
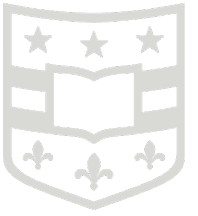


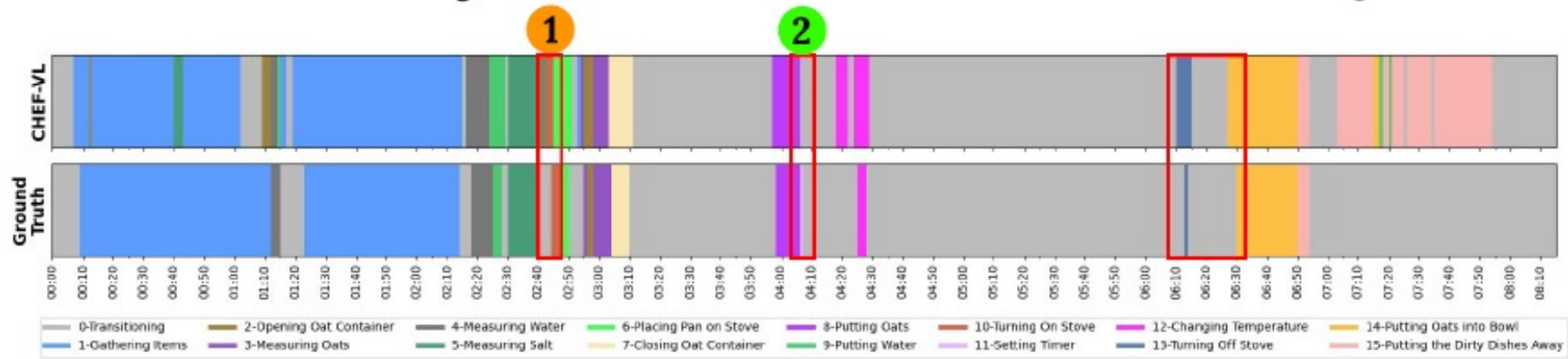
Fig. 8. Overview of the online sequencing error detection process with dependency-based filtering and partial-order-based prerequisite checking.



Predicted as "Turning on the Stove".



Predicted as "Transitioning".



Model results

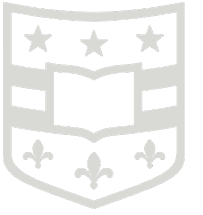
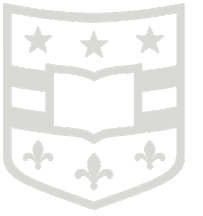


Table 3. Comparison of methods on HAR performance on the Oatmeal107 dataset. We report mean Average Precision (mAP), Accuracy, Accuracy without Transitioning, and Edit Score. The best performance for each metric is bolded, and the second-best is underlined.

Method	mAP (%)	Accuracy (%)	Accuracy without Transitioning (%)	Edit Score (%)
LSTR	45.31	84.63	75.85	53.40
GPT-4o	19.62	63.37	58.80	14.99
Qwen2.5-VL	15.01	53.23	42.76	12.28
Qwen2.5-VL-Finetune	<u>48.54</u>	78.38	80.99	37.25
LLaVA-Finetune	33.96	65.10	78.70	27.93
CHEF-VL (Ours)	50.48	<u>80.10</u>	<u>80.00</u>	<u>40.15</u>

- CHEF-VL handles the challenges introduced by task complexity and visual similarity in the kitchen environment
- CHEF-VL supports downstream sequencing error detection by integrating action and state predictions



Next steps

- Evaluate the clinical utility of the Smart Kitchen system to support independent living at home
 - Stakeholder input
 - Family member input
- Provide system-based cues to support performance
 - Can cues be given in an appropriate timeframe to support performance?
 - Are these cues helpful for stakeholders?
- Does CHEF-VL generalize to other cooking tasks?



**Thank you for this opportunity
to present to you today**

lconnor@wustl.edu

